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## **Magnitude or Direction? Seasonal Variation of Inter-limb Asymmetry in Elite Academy Soccer Players**

### **Abstract**

Previous research has highlighted a distinct lack of longitudinal data for asymmetry. The aims of the present study were to provide seasonal variation data for the magnitude and direction of asymmetry. Eighteen elite male academy soccer players (under-23) performed unilateral countermovement jumps (CMJ) and unilateral drop jumps (DJ) during pre, mid and end of season time points. Recorded metrics for asymmetry included: jump height and concentric impulse for the CMJ, and jump height and reactive strength index for the DJ. The magnitude of asymmetry showed trivial to small changes throughout the season (CMJ effect size range = -0.43 to 0.05; DJ effect size range = -0.18 to 0.41). However, Kappa coefficients showed poor to substantial levels of agreement for the direction of asymmetry during the CMJ (Kappa = -0.06 to 0.77) and DJ (Kappa = -0.10 to 0.78) throughout the season. These data show that when monitoring asymmetry, the magnitude alone may provide a false impression of consistent scores over time. In contrast, monitoring the direction of asymmetry highlights its task and variable nature, and is suggested as a useful tool for practitioners who wish to monitor asymmetry over the course of a competitive soccer season.

**Key Words:** Between-limb differences; longitudinal tracking; soccer performance.

### Introduction

Jump tests are commonly used for monitoring performance changes and neuromuscular readiness in soccer athletes (9,19,26,31). However, longitudinal tracking throughout a season has been reported more sparingly. Casajus (9) monitored jump height during the countermovement jump (CMJ) and squat jump (SJ) tests in 15 professional soccer players, although data was only collected in September and February, which likely represent time points near the start and middle of a competitive season. Results showed no significant differences between time points. In contrast, the CMJ was used by Haugen (19) to assess seasonal variation in vertical jump performance in 44 Norwegian professional soccer players. Results showed mean jump height (in cm) of  $37.4 \pm 4.0$  for pre-season,  $38.1 \pm 4.0$  in-season, and  $38.6 \pm 3.9$  in the off-season. Significant differences were evident between pre-season and off-season, with effect sizes between time points ranging from 0.15-0.30. With significant changes in jump performance potentially evident throughout a soccer season, this type of monitoring may allow practitioners a better understanding regarding the specific demands players may face at different stages of the season.

Players often experience heightened training volumes during pre-season (16) and increased fixture density during mid-season (8), with the effects of cumulated loading potentially driving sport-specific adaptations by the end of the season (1,27). In addition, it appears that bilateral jump tests have been the primary method to track longitudinal changes in vertical jump performance (9,11,19), with limited data available to examine seasonal changes in unilateral tests. Despite bilateral jumps often being employed in routine test batteries with strong reliability (11,17), many sporting actions occur unilaterally for soccer players (e.g., sprinting, cutting, kicking). Thus, the implementation of unilateral jump tests seems like an ecologically valid suggestion for the assessment of jump performance. Furthermore, the aforementioned studies only tracked jump height, which has been shown to be somewhat insensitive to change

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when using jump tests to detect neuromuscular fatigue (17). Thus, a more in-depth analysis of jump strategy may provide more meaningful information relating to how jumps are performed, which practitioners can use to detect acute changes in their athletes' movement patterns (13,17). Furthermore, this information is scarce using unilateral jump test measures and is warranted longitudinally.

Recent research has investigated the prevalence of asymmetry from unilateral jump tests and reported correlations with measures of athletic performance (3,6,15,22,24). However, these studies only reported asymmetry scores at a single time point. Previous literature has highlighted that longitudinal data pertaining to asymmetry is missing (7,25) and could be used to inform the monitoring process. Furthermore, seasonal changes in the direction of asymmetry to provide an indication as to which limb is dominant are also unknown. Bishop et al. (2) examined agreement between peak force and impulse metrics during the unilateral isometric squat, CMJ and broad jump tests. With the exception of concentric impulse between jump tests, results typically showed poor levels of agreement between the different tests (Kappa range = -0.34 to 0.32), indicating that the direction of asymmetry is both task and variable-dependent, much like the magnitude (22,23). This is further supported in a study which used a test-retest design to determine consistency in the direction of asymmetry between sessions (4). Results showed substantial levels of agreement for jump height and peak force asymmetries during the unilateral CMJ (Kappa range = 0.64-0.66), but only fair to moderate levels of agreement for jump height and reactive strength asymmetries during the unilateral drop jump test (Kappa range = 0.36-0.56) (4). However, these data are for single and double testing sessions, with a paucity of in-depth longitudinal monitoring to detect asymmetry using unilateral jump tests and the varying nature of both the magnitude and direction of asymmetry.

Therefore, the aims of the present study were to: 1) provide seasonal variation data for the magnitude of inter-limb asymmetry and, 2) provide seasonal variation data for the direction of

inter-limb asymmetry. Given no comparable data has been published longitudinally on asymmetry, developing a meaningful hypothesis was challenging. However, given previous research has acknowledged the variable nature of side-to-side differences, it was suggested that significant changes in both the magnitude and direction of asymmetry would be evident across a competitive soccer season.

## Methods

### *Experimental Approach to the Problem*

This study used a repeated measures design over three time points during the course of a competitive season in elite male academy soccer players. Jump data was collected and inter-limb asymmetry monitored for the unilateral CMJ and unilateral DJ tests during pre-season (July), mid-season (January) and end-season (May). Players performed a standardized warm up procedure starting with dynamic stretches and the same procedures were adhered to at all time points. Specifically, this consisted of 1 x 10 repetitions of forward and lateral lunges on each leg, inchworms, spidermans and bodyweight squats, followed by three practice trials of each jump test at 60, 80 and 100% of perceived maximal effort. Three minutes of rest was provided between the last practice trial and the start of the first jump test and 60-seconds of rest was provided between trials during the data collection process, with jump testing performed in a randomized order.

### *Subjects*

Eighteen elite academy male soccer players (age:  $19.0 \pm 2.2$  years; height:  $1.80 \pm 0.07$  m; body mass:  $73.3 \pm 9.0$  kg) from the under-23 age group in a Category 3 academy of a professional

soccer club volunteered to participate in this study. A priori power analysis using G\*Power (Version 3.1, University of Dusseldorf, Germany) showed that 20 players were needed in order to implement a statistical power of 0.8 and a type 1 alpha level of 0.05. Thus, with 18 subjects, the present study showed statistical power of 0.75. All players had a minimum of two years structured strength and conditioning training experience and a minimum of six years' competitive soccer experience at the academy level. Players were required to be injury-free at the time testing and in the preceding four weeks prior to each test session. Written informed consent was provided from all subjects (and their guardians for any player under the age of 18), and each player was also cleared to participate in testing by the club's medical department. Ethical approval was provided by the [deleted for peer review] research and ethics committee.

### *Procedures*

*Unilateral Countermovement Jump (CMJ).* Players were instructed to step onto a single uniaxial force platform (PASPORT force plate, PASCO Scientific, California, USA; size = 0.42 x 0.42 m) sampling at 1000 Hz, with their designated test leg and hands placed on hips which were required to remain in the same position for the duration of the test. The jump was initiated by performing a countermovement to a self-selected depth before accelerating vertically as fast as possible into the air. The test leg was required to remain fully extended throughout the flight phase of the jump before landing back onto the force plate as per the set up. The non-jumping leg was slightly flexed with the foot hovering at approximately mid-shin level and no additional swinging of this leg was allowed during trials. Recorded metrics included jump height and concentric impulse, with definitions for their quantification in line with suggestions by Gathercole et al. (17) and Chavda et al. (10). Jump height was defined as the maximum height achieved calculated from velocity at take-off squared divided by  $2 \times 9.81$

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(where 9.81 equals gravitational force). Concentric impulse was defined as the net force multiplied by the time taken to produce it, i.e., the area under the net force-time curve. Specifically, this was determined by identifying the integral of force from when the system mass was at zero velocity to take-off (10). The first meaningful change in force was established when values surpassed  $\pm$  five standard deviations (SD) of each participant's body weight, minus 30 milliseconds, in line with suggestions from Owen et al. (28). The force plate was calibrated prior to each data collection and all force traces were extracted unfiltered, and subsequently copied into a custom-made spreadsheet previously suggested (10) for further analysis. Each athlete performed three trials on each leg with an average score taken on each side to compute the inter-limb asymmetry value.

*Unilateral Drop Jump (DJ).* The unilateral DJ was performed using the OptoJump™ measurement system (Microgate, Bolzano, Italy) with athletes required to step off an 18 cm box; this height chosen in line with previous research using this test (23,24). With hands fixed on hips, participants were required to step off the box with their designated test leg which subsequently landed on the floor between the optical measurement system below. Upon landing, participants were instructed to minimize ground contact time and jump as high as possible thereafter in line with previous suggestions (29). Recorded metrics included jump height (calculated from the flight time method) and reactive strength index (RSI), quantified using the equation flight time/ground contact time (24). Three jumps were performed on each leg with each side averaged to calculate an inter-limb asymmetry score.

## *Statistical Analysis*

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All data were initially recorded as means and SD in Microsoft Excel and later transferred to SPSS (version 25.0; SPSS, Inc., Armonk, NY, USA). Normality was assessed using the Shapiro-Wilk test and showed that inter-limb asymmetry values were not normally distributed. Inter-limb asymmetries were quantified as a percentage difference between limbs using the formula:  $(100/(\text{maximum value}) * (\text{minimum value}) * -1 + 100)$ , as proposed by Bishop et al. (5). In order to determine the direction of asymmetry, an 'IF function' was added on to the end of the formula in Microsoft Excel:  $*IF(\text{left} < \text{right}, 1, -1)$  (2,4). Within-session reliability of test measures was computed at each time point using an average measures two-way random intraclass correlation coefficient (ICC) with absolute agreement and 95% confidence intervals, and the standard error of the measurement (SEM) using the formula:  $\sqrt{\text{mean square of error}}$  (33). Interpretation of ICC values was in accordance with previous research by Koo and Li (21) where values  $> 0.9$  = excellent,  $0.75-0.9$  = good,  $0.5-0.75$  = moderate, and  $< 0.5$  = poor.

Friedman's ANOVA was conducted to determine differences in asymmetry scores between time points for all metrics, with statistical significance set at  $p < 0.05$ . The magnitude of change was calculated between time points using Cohen's  $d$  effect sizes (ES) with 95% confidence intervals using the formula:  $(\text{Mean}_{T1} - \text{Mean}_{T2}) / \text{SD}_{\text{pooled}}$ , where T1 and T2 represent the respective time points in question (e.g., pre, mid or end-season). These were interpreted in line with Hopkins et al. (20) where  $< 0.2$  = trivial;  $0.2-0.6$  = small;  $0.6-1.2$  = moderate;  $1.2-2.0$  = large;  $2.0-4.0$  = very large; and  $> 4.0$  = near perfect.

Kappa coefficients were calculated to determine the levels of agreement for how consistently an asymmetry favoured the same side (direction of asymmetry) when comparing the different time points measured. This method was chosen because the Kappa coefficient describes the proportion of agreement between two methods after any agreement by chance has been removed (12). Kappa values were interpreted in line with suggestions from Viera and Garrett (32), where  $\leq 0$  = poor,  $0.01-0.20$  = slight,  $0.21-0.40$  = fair,  $0.41-0.60$  = moderate,  $0.61-0.80$  =



substantial, and 0.81-0.99 = almost perfect. Given that asymmetry is a ratio number (i.e., calculated as a percentage from left and right scores), use of the Kappa coefficient serves as an alternative statistical method to more traditional methods of reliability (e.g., coefficient of variation and intraclass correlation coefficient), as it is able to account for consistency in the direction of asymmetry, something which traditional measures cannot accomplish when using the absolute percentage value.

## Results

Reliability data are presented for each time point in Table 1. Relative reliability (ICC) ranged from moderate to excellent for CMJ metrics (ICC = 0.75-0.97) and DJ metrics (ICC = 0.88-0.98) across all time points. Mean inter-limb asymmetry data are presented for each time point in Table 2. Trivial to small non-linear changes were shown throughout the season for the unilateral CMJ (ES range = -0.43 to 0.05) and unilateral DJ (ES range = -0.18 to 0.41) tests. The SEM was also computed for asymmetry values at each time point: CMJ height (pre-season = 2.26%; mid-season = 1.65%; end-season = 1.61%), concentric impulse (pre-season = 1.73%; mid-season = 1.43%; end-season = 1.28%), DJ height (pre-season = 1.56%; mid-season = 2.16%; end-season = 2.02%), RSI (pre-season = 1.46%; mid-season = 1.45%; end-season = 1.90%).

Kappa coefficients and accompanying descriptors for how consistently asymmetry favoured the same limb between time points are presented in Table 3. For both tests, levels of agreement ranged from poor to substantial (CMJ = -0.06 to 0.77) and (DJ = -0.10 to 0.78), highlighting the variable nature in the direction of asymmetry throughout the soccer season. Individual asymmetry scores have also been presented for each time point for the CMJ (Figure 1 = jump height; Figure 2 = concentric impulse) and DJ (Figure 3 = jump height; Figure 4 = RSI) tests,

indicating pronounced within-participant variability. For the CMJ, 13 players exhibited consistency in the direction of asymmetry for jump height at all time points, whereas only 6 showed consistency for concentric impulse across the season. For the DJ, 8 and 11 players showed consistency in the direction of asymmetry across the season for jump height and RSI, respectively.

***\*\* Insert Tables 1-3 about here \*\****

***\*\* Figures 1-4 about here \*\****

## **Discussion**

The aim of the present study was to provide seasonal variation data for the magnitude and direction of inter-limb asymmetry. Results showed the magnitude of asymmetry remained consistent throughout the season, showing no significant changes. However, the direction of asymmetry varied considerably with poor to substantial levels of agreement for both jump tests throughout the season.

Mean inter-limb asymmetry values (Table 2) showed relatively consistent scores with between-limb differences for the CMJ ranging from 8.61-11.19% (jump height) and 6.34-9.14% (concentric impulse). For the DJ, mean asymmetry ranged from 8.42-10.42% (jump height) and 8.27-10.80% (RSI), with all values on both tests representing trivial to small changes (ES range = -0.43 to 0.41). However, caution should be applied when interpreting these data and concluding that inter-limb asymmetry is consistent throughout a soccer season. Firstly, Table 2 shows the large SD for each metric when using the mean asymmetry score and may explain why only trivial to small changes were evident between time points. Bishop et al. (2) suggested

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that an individual approach to assessing asymmetry is likely needed in order to establish meaningful data, because of its highly variable nature and is supported in the present study by Figures 1-4. For example, in Figure 1, athlete 1 is showing three very different asymmetry scores at each time point, but does show consistency in right limb dominance across the season. When each athlete is viewed across all figures, it is clear that there is often inherent change in the magnitude of asymmetry; thus, it is suggested that a more individual approach to data interpretation is likely needed, and is in line with recent suggestions on the topic (2,4).

Recent literature has suggested investigating the direction of asymmetry in an attempt to establish how consistently asymmetry favours the same limb across different tests (2) or time points (4). Our results showed that the direction of asymmetry is metric-specific and highly variable within each jump test (Table 3). During the CMJ, jump height showed substantial levels of agreement ( $\text{Kappa} = 0.77$ ) when comparing asymmetry data from mid to end-season, but only fair levels of agreement ( $\text{Kappa} = 0.35$ ) from pre to end-season. In contrast, concentric impulse showed poor to fair levels of agreement ( $\text{Kappa} = -0.06$  to  $0.33$ ). These data indicate that strategy-based metrics (i.e., impulse) show substantial variation in asymmetry in comparison to task output metrics such as jump height; thus, may be too inconsistent to use when profiling existing side-to-side differences. Although somewhat anecdotal, this may be explained by the fact that asymmetry is a ratio number (i.e., it is calculated from left and right scores). In addition, impulse is derived from net force and time; thus, when asymmetry data is derived for impulse (which already has two constituent parts), it seems plausible to suggest that larger amounts of variability are absorbed in comparison to an outcome measure such as jump height. Therefore, the direction of asymmetry may consequently be affected and exhibit less consistency.

Our results also showed that the DJ displays inherent variability in the direction of asymmetry. Substantial levels of agreement were shown for jump height when comparing mid to end-

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season ( $Kappa = 0.68$ ) and RSI when comparing pre to mid-season ( $Kappa = 0.78$ ). However, all other time points showed poor to fair levels of agreement for the direction of asymmetry, further highlighting the variable nature of asymmetry in healthy soccer players and the need to interpret data from an individual perspective (2,4). For example, in Figure 3, athlete 5 starts the season right limb dominant with an asymmetry of 14%, but then measures left limb dominant (10%) by mid-season, resulting in a 24% shift in the imbalance. To provide another example, in Figure 4, athlete 1 exhibits right limb dominance consistently throughout the season. However, there is an exponential increase in the magnitude of asymmetry starting at 10% and ending in 34%. Thus, large increases in the magnitude of asymmetry or shifts in limb dominance likely indicate that individual monitoring is key for practitioners.

When interpreting the findings of the current study, there are some limitations that should be acknowledged. Firstly, training or competition load data was not available throughout the present study; thus, understanding why such variations occurred in the direction of asymmetry is challenging. Soccer athletes frequently perform high-intensity actions unilaterally such as jumping, sprinting and changing direction (30). Given the positional differences and variations in team formations that often associated with soccer, it is unlikely that these actions will occur in an equal amount on each limb (18). In addition, limb dominance is likely to change depending on the task in question (14). Thus, investigating the interaction between asymmetry and in-game soccer demands, seems like a potentially useful line of investigation in order to determine why such variability exists. Secondly, the sample size used in the present study was relatively small and results can only be applied to this particular soccer academy. Thus, if profiling between-limb differences are deemed necessary by soccer practitioners, they are advised to do so with their own players longitudinally.

### **Practical Applications**

In summary, these findings suggest that the mean asymmetry value disguises the inherent variability that seems to accompany inter-limb asymmetry scores and provides a false impression of consistent scores over time. Therefore, practitioners are advised to prioritise calculating the direction of asymmetry in order to determine whether consistency in limb dominance is evident. This may provide a more meaningful understanding as to whether functional asymmetries exist as a consequence of sport-specific demands (i.e., playing the same position over time), which has been suggested as a reason for the prevalence of asymmetry previously (18). It is recognised that not all practitioners will know how to quantify the direction of asymmetry; thus, interested readers are advised to view the following video link:

<https://www.youtube.com/watch?v=PVOoBb4rNMk>.

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**Table 1.** Reliability data for test measures at pre, mid and end of season time points.

Test/Metric	Pre-season		Mid-season		End-season	
	<i>SEM</i>	<i>ICC (95% CI)</i>	<i>SEM</i>	<i>ICC (95% CI)</i>	<i>SEM</i>	<i>ICC (95% CI)</i>
<i>UCMJ:</i>						
Jump height-L (m)	0.01	0.94 (0.88-0.98)	0.01	0.97 (0.94-0.99)	0.01	0.93 (0.85-0.97)
Jump height-R (m)	0.01	0.86 (0.68-0.94)	< 0.01	0.97 (0.93-0.99)	0.01	0.80 (0.57-0.92)
CON impulse-L (N·s)	6.08	0.95 (0.90-0.98)	2.95	0.97 (0.94-0.99)	5.11	0.88 (0.73-0.95)
CON impulse-R (N·s)	6.62	0.92 (0.82-0.97)	3.59	0.94 (0.87-0.98)	6.38	0.75 (0.49-0.90)
<i>UDJ:</i>						
Jump height-L (m)	0.01	0.96 (0.92-0.99)	0.01	0.98 (0.96-0.99)	0.01	0.97 (0.94-0.99)
Jump height-R (m)	0.01	0.97 (0.93-0.99)	0.01	0.96 (0.92-0.99)	0.01	0.93 (0.84-0.97)
RSI-L	0.05	0.95 (0.88-0.98)	0.04	0.97 (0.93-0.99)	0.05	0.96 (0.92-0.99)
RSI-R	0.06	0.97 (0.92-0.99)	0.06	0.95 (0.90-0.98)	0.06	0.88 (0.74-0.95)
SEM = standard error of the measurement; ICC = intraclass correlation coefficient; CI = confidence intervals; UCMJ = unilateral countermovement jump; L = left; R = right; m = metres; CON = concentric; N·s = Newton seconds; UDJ = unilateral drop jump; RSI = reactive strength index; s = seconds; CODS = change of direction speed.						

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**Table 2.** Mean inter-limb asymmetry  $\pm$  SD and effect size (95% confidence intervals) data between pre, mid and end-season.

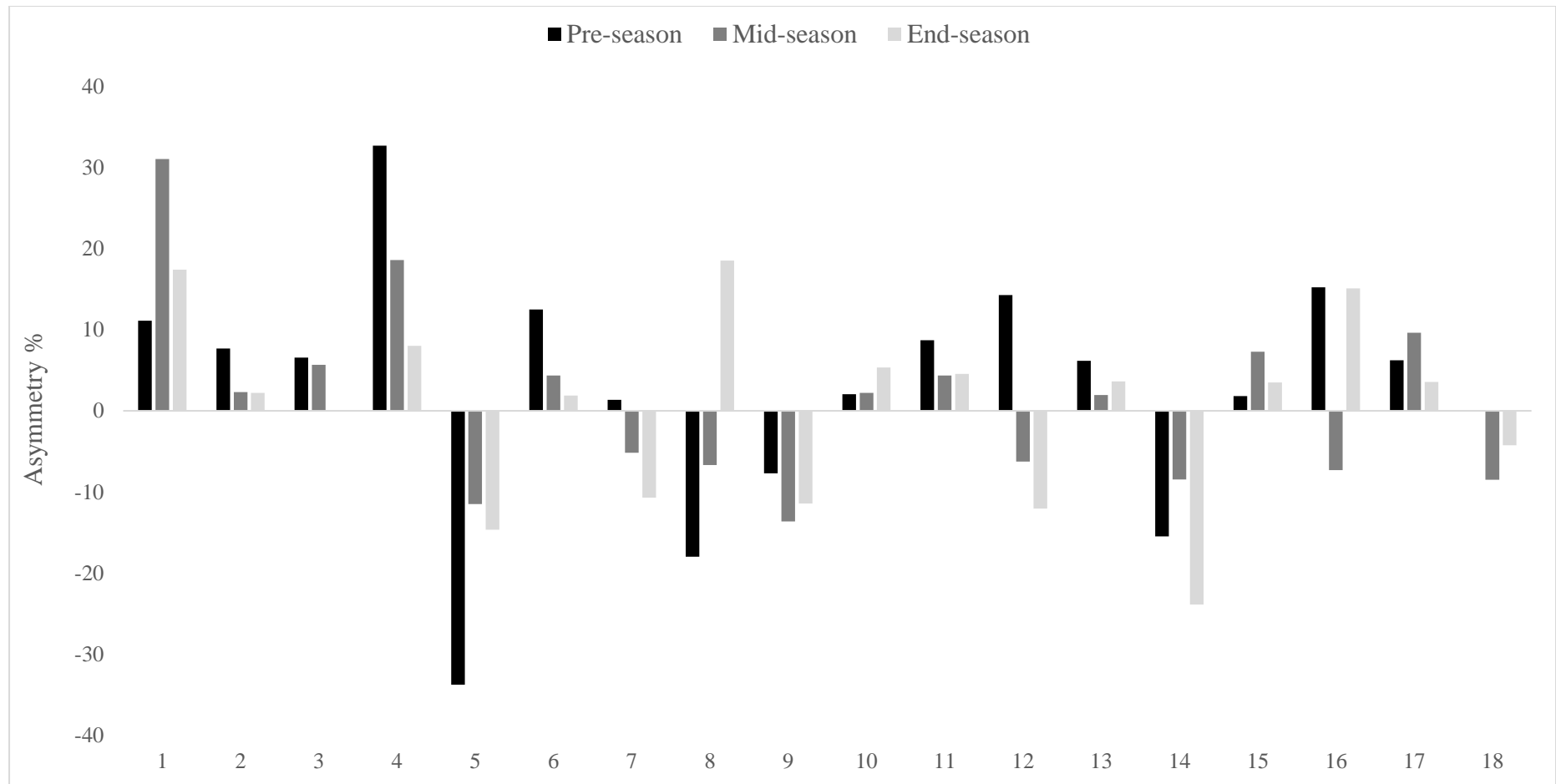
Test/Metric	Asymmetry % (Pre-season)	Asymmetry % (Mid-season)	Asymmetry % (End-season)	Effect Size (Pre to Mid)	Effect Size (Pre to End)	Effect Size (Mid to End)
<i>UCMJ:</i>						
Jump height	11.19 $\pm$ 9.58	8.61 $\pm$ 6.99	8.93 $\pm$ 6.83	-0.31 (-0.96 to 0.35)	-0.27 (-0.93 to 0.38)	0.05 (-0.61 to 0.70)
CON impulse	9.14 $\pm$ 7.35	8.13 $\pm$ 6.07	6.34 $\pm$ 5.41	-0.15 (-0.80 to 0.50)	-0.43 (-1.09 to 0.23)	-0.31 (-0.97 to 0.35)
<i>UDJ:</i>						
Jump height	8.42 $\pm$ 6.61	10.13 $\pm$ 9.15	10.42 $\pm$ 8.57	0.21 (-0.44 to 0.87)	0.26 (-0.39 to 0.92)	0.03 (-0.62 to 0.69)
RSI	8.27 $\pm$ 6.18	10.80 $\pm$ 6.14	9.49 $\pm$ 8.05	0.41 (-0.25 to 1.07)	0.17 (-0.48 to 0.82)	-0.18 (-0.84 to 0.47)
UCMJ = unilateral countermovement jump; UDJ = unilateral drop jump; GCT = ground contact time; RSI = reactive strength index.						

## Seasonal Variation of Asymmetry

**Table 3.** Kappa coefficients and accompanying descriptors for levels of agreement describing how consistently asymmetry favoured the same side across pre, mid and end-season.

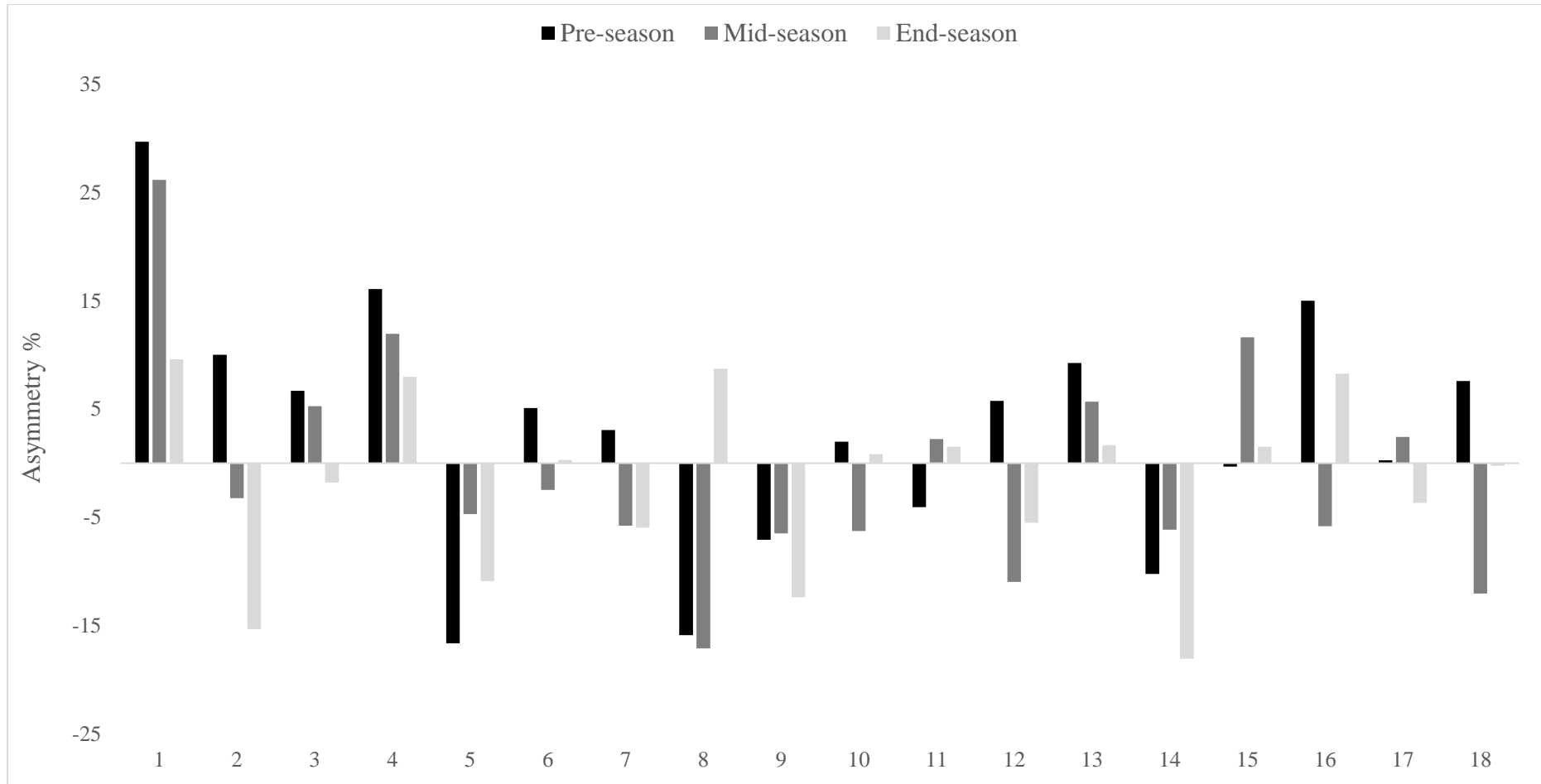
Test/Metric	Pre to Mid <i>Kappa (Descriptor)</i>	Pre to End <i>Kappa (Descriptor)</i>	Mid to End <i>Kappa (Descriptor)</i>
<i>UCMJ:</i>			
Jump height	0.52 (Moderate)	0.35 (Fair)	0.77 (Substantial)
Concentric impulse	0.07 (Slight)	-0.06 (Poor)	0.33 (Fair)
<i>UDJ:</i>			
Jump height	0.20 (Slight)	-0.10 (Poor)	0.68 (Substantial)
Reactive strength index	0.78 (Substantial)	0.22 (Fair)	0.22 (Fair)
UCMJ = unilateral countermovement jump; UDJ = unilateral drop jump.			

## Seasonal Variation of Asymmetry



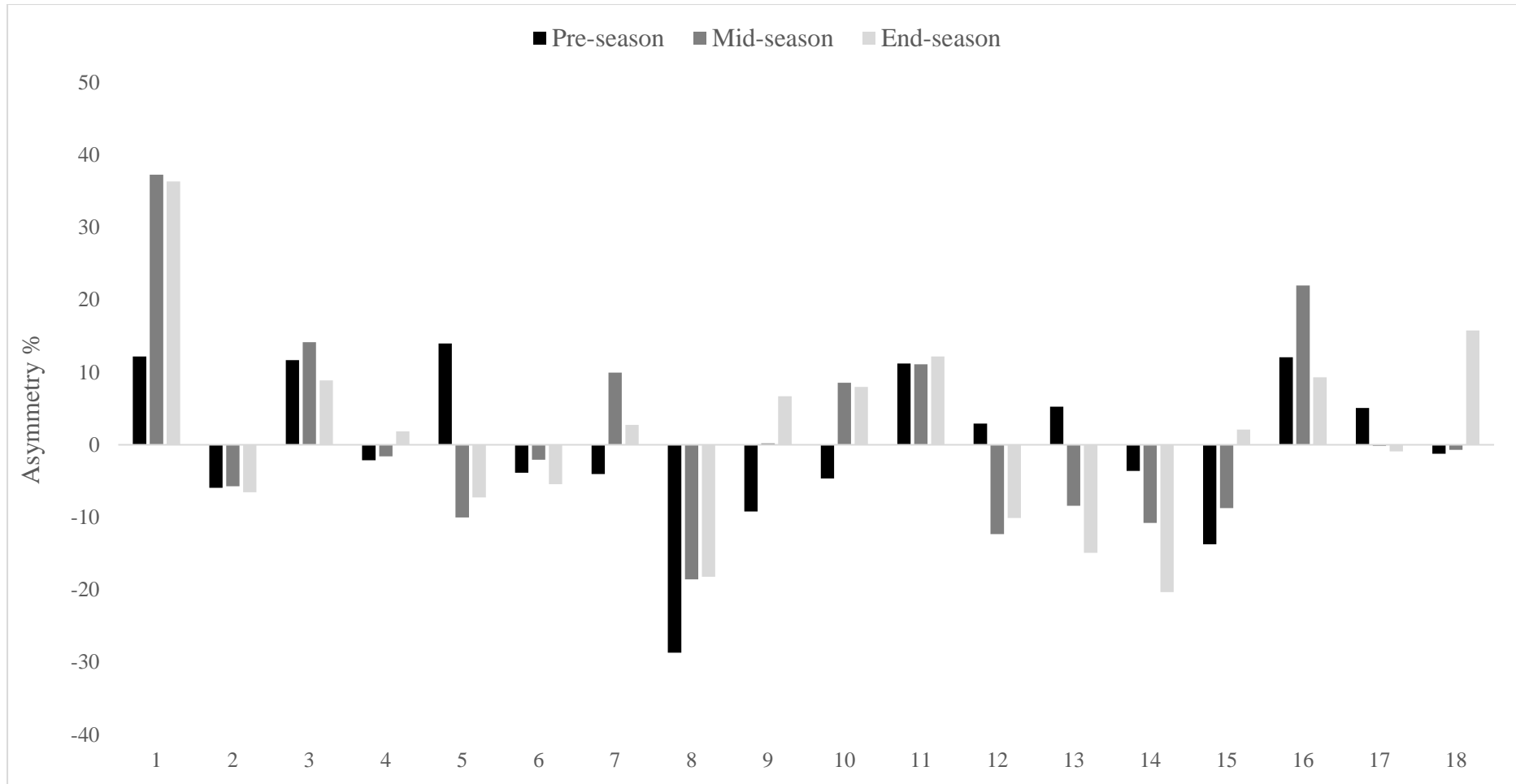
**Figure 1.** Individual asymmetry data for jump height during the unilateral countermovement jump. N.B: above 0 means asymmetry favours the right leg; below 0 means asymmetry favours the left leg.

## Seasonal Variation of Asymmetry



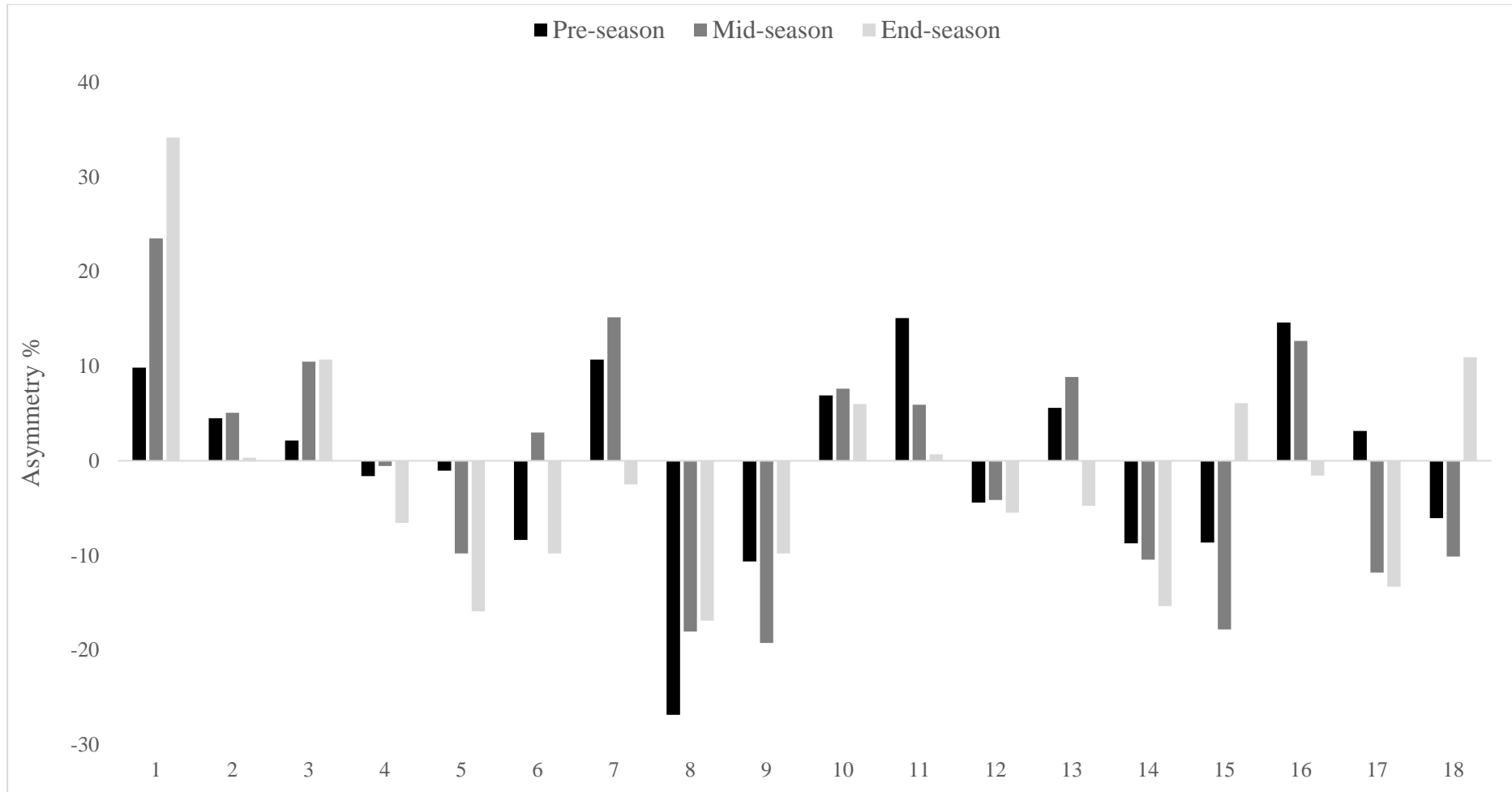
**Figure 2.** Individual asymmetry data for concentric impulse during the unilateral countermovement jump. N.B: above 0 means asymmetry favours the right leg; below 0 means asymmetry favours the left leg.

### Seasonal Variation of Asymmetry



**Figure 3.** Individual asymmetry data for jump height during the unilateral drop jump. N.B: above 0 means asymmetry favours the right leg; below 0 means asymmetry favours the left leg.

## Seasonal Variation of Asymmetry



**Figure 4.** Individual asymmetry data for reactive strength index during the unilateral drop jump. N.B: above 0 means asymmetry favours the right leg; below 0 means asymmetry favours the left leg.